Claims

1. A method for removal of one or more particles on a surface, the method comprising:
providing an assembly of I activatable transducers, with $I \geq 2$, with each transducer being capable of generating at least one cavity in a selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on a surface suspended in the particle removal liquid;
immersing the transducer assembly in a selected test liquid;
activating at least one transducer of said transducer assembly;
measuring cavity density produced by the at least one transducer;
determining whether to adjust at least one parameter of the at least one transducer;
removing the transducer assembly from the test liquid and immersing the transducer assembly in the particle removal liquid; and
activating the at least one transducer in the particle removal liquid, and allowing at least one cavity produced by at least one of the transducers to collapse and to thereby remove at least one particle on a surface immersed in the particle removal liquid.
2. The method of claim 1, further comprising
electrically connecting said transducer assembly to a servo control unit, said servo control unit adjusting said at least one parameter if adjustment occurs.
3. The method of claim 2, further comprising disconnecting said transducer assembly from said servo control unit before activating the at least one of said transducers in the particle removal liquid.
4. The method of claim 1, further comprising selecting said particle removal liquid and said test liquid to be substantially the same liquid.
5. The method of claim 1, further comprising selecting said particle removal liquid from the group of liquids consisting of H_2O, NH_3, H_2O_2, H_2SO_4 and O_3 dissolved in DI water.
6. The method of claim 1, further comprising selecting said test liquid from the group of liquids consisting of DI water and DI water plus an inert fluid drawn from Ne, Ar, Kr and Xe.

7. The method of claim 1, further comprising causing each of the at least one transducers to emit a selected output frequency in said particle removal liquid, where each selected frequency is in a range 100-3000 KHz.
8. The method of claim 1, further comprising:
suspending at least a second surface in said particle removal liquid, when said at least one transducer is activated; and
allowing at least one additional cavity produced by said at least transducer to collapse and to thereby remove at least one particle on the second surface immersed in said particle removal liquid.
9. A method for removal of one or more particles on a surface, the method comprising:
providing an assembly of two or more activatable transducers, with each transducer being capable of generating at least one cavity in a selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on a surface suspended in the particle removal liquid;
immersing the transducer assembly in a selected test liquid;
activating a first transducer in the assembly to produce at least one cavity in the test liquid, estimating a first representative cavitation density $\rho_{cav}(1)$ produced by the first transducer and computing a first difference, $|\rho_{cav}(1) - \rho_{cav}(ref)|$, where $\rho_{cav}(ref)$ is a selected reference cavitation density,
when the magnitude of the first difference is greater than a selected difference threshold $\Delta\rho_{thr}$, adjusting at least one parameter on the first transducer so that at least one of the following conditions is satisfied: (i) the magnitude of the first difference is reduced to no greater than the difference threshold and (ii) the magnitude of the first difference is minimized;
activating a second transducer in the assembly to produce at least one cavity in the test liquid, estimating a second representative cavitation density $\rho_{cav}(2)$ produced by the second transducer, and computing a second difference, $|\rho_{cav}(2) - \rho_{cav}(ref)|$;
when the magnitude of the second difference is greater than $\Delta\rho_{thr}$, adjusting at least one parameter on the second transducer so that at least one of the following conditions is satisfied: (i) the magnitude of the second difference is

reduced to no greater than the difference threshold and (ii) the magnitude of the second difference is minimized;
removing the transducer assembly from the test liquid and immersing the transducer assembly in the particle removal liquid; and
activating at least the first and second transducers in the particle removal liquid, and allowing at least one cavity produced by at least one of the first and second transducers to collapse and to thereby remove at least one particle on the surface immersed in the particle removal liquid.

10. A method for removal of one or more particles on a surface, the method comprising:
providing an assembly of I activatable transducers, with $I \geq 2$, with each transducer being capable of generating at least one cavity in a selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on a surface suspended in the particle removal liquid;
immersing the transducer assembly in a selected test liquid;
activating each of a subset of I' transducers in the assembly, numbered $i' = 1, \ldots, I'$, with $1 < I' \leq I$ to produce at least one cavity in the test liquid for each activated transducer in the subset, estimating a representative cavitation density $\rho_{cav}(i')$ produced by transducer number i', and computing a density difference, $\Delta\rho(i') = |\rho_{cav}(i') - \rho_{cav}(ref)|$, for each of $i' = 1, \ldots, I'$, where $\rho_{cav}(ref)$ is a selected reference cavitation density,
forming a statistical average $D\{\Delta\rho(i1), \ldots, \Delta\rho(I')\}$ of the I' density differences;
when the statistical average $D\{\Delta\rho(i1), \ldots, \Delta\rho(I')\}$ is greater than a selected difference threshold $\Delta\rho_{thr}$, adjusting at least one parameter for at least one of the I' transducers so that at least one of the following conditions is satisfied: (i) the statistical average $D\{\Delta\rho(i1), \ldots, \Delta\rho(I')\}$ after the adjustment is reduced to a value no greater than the difference threshold and (ii) the magnitude of the statistical average $D\{\Delta\rho(i1), \ldots, \Delta\rho(I')\}$ is minimized;
removing the transducer assembly from the test liquid and immersing the transducer assembly in the particle removal liquid; and
activating at least the I' transducers in the particle removal liquid, and allowing at least one cavity produced by at least one of the I' transducers to collapse and

to thereby remove at least one particle on the surface immersed in the particle removal liquid.

11. The method of claim 10, further comprising choosing said statistical average to be given approximately by

$$D(\Delta\rho(1),\ldots\Delta\rho(I))=\left\{\sum_{i=1}^{I}\mathrm{w}(\mathrm{i})\times\{\Delta\rho(i)\}^{p}\right\}^{1/p}$$

where p is a selected positive number and w(i') is a non-negative weight coefficient satisfying a constraint

$$\sum_{i=1}^{I}\mathrm{w}(\mathrm{i})=1$$

12. A system for removal of one or more particles on a surface, the system comprising:

a container of a selected test liquid that receives an assembly of two or more activatable transducers, with each transducer being capable of generating at least one cavity in a selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on a surface suspended in the particle removal liquid;

a first transducer activation and measurement mechanism to activate a first transducer in the assembly to produce at least one cavity in the test liquid, to estimate a first representative acoustic cavitation density $\rho_{cav}(1)$ produced by the first transducer, and to compute a first difference, $|\rho_{cav}(1) - \rho_{cav}(ref)|$, where $\rho_{cav}(ref)$ is a selected reference cavity diameter,

a first transducer adjustment mechanism configured so that, when the magnitude of the first difference is greater than a selected difference threshold $\Delta\rho_{thr}$, at least one parameter on the first transducer is adjusted so that at least one of the following conditions is satisfied: (i) the magnitude of the first difference is reduced to no greater than the difference threshold and (ii) the magnitude of the first difference is minimized;

a second transducer activation and measurement mechanism to activate a second transducer in the assembly to produce at least one cavity in the test liquid, to estimate a representative pre-implosion cavity diameter $\rho_{cav}(2)$, and to compute a second difference, $|\rho_{cav}(2) - \rho_{cav}(ref)|$;

a second transducer adjustment mechanism configured so that, when the magnitude of the second difference is greater than $\Delta\rho_{thr}$, at least one parameter on the second transducer is adjusted so that at least one of the following conditions is satisfied: (i) the magnitude of the second difference is reduced to no greater than the difference threshold and (ii) the magnitude of the second difference is minimized;

an assembly repositioning mechanism to remove the transducer assembly from the test liquid and to immerse the transducer assembly in the particle removal liquid; and

a transducer assembly activation mechanism to activate at least the first and second transducers in the particle removal liquid, and to allow at least one cavity produced by at least one of the first and second transducers to collapse and to thereby remove at least one particle on the surface immersed in the particle removal liquid.

13. A system for removal of one or more particles on a surface, the system comprising:

an assembly of I activatable transducers, with $I \geq 2$, with each transducer being capable of generating at least one cavity in a selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on a surface suspended in the particle removal liquid;

a first container of a selected test liquid in which the transducer assembly can be immersed;

a transducer activation mechanism for activating each of a subset of I' transducers in the assembly, numbered $i' = 1, \ldots, I'$, with $1 < I' \geq I$ to produce at least one cavity in the test liquid for each activated transducer in the subset, where the activation mechanism estimates a representative cavitation density $\rho_{cav}(i')$ produced by transducer number i' and computes a density difference, $\Delta\rho(i') = |\rho_{cav}(i') - \rho_{cav}(ref)|$, for each of $i' = 1, \ldots, I'$, where $\rho_{cav}(ref)$ is a selected reference cavitation density,

a computing device that is programmed to:

receive the estimated representative cavitation densities $r_{cav}(i')$ and forms a statistical average $D\{\Delta\rho(i1), \ldots, \Delta\rho(I')\}$ of the I' density differences; and

when the statistical average $D\{\Delta\rho(i1), \dots, \Delta\rho(I')\}$ is greater than a selected difference threshold $\Delta\rho_{thr}$, to adjust at least one parameter for at least one of the I' transducers so that at least one of the following conditions is satisfied: (i) the statistical average $D\{\Delta\rho(i1), \dots, \Delta\rho(I')\}$ after the adjustment is reduced to a value no greater than the difference threshold and (ii) the magnitude of the statistical average $D\{\Delta\rho(i1), \dots, \Delta\rho(I')\}$ is minimized;

an assembly removal mechanism for removing the transducer assembly from the test liquid and immersing the transducer assembly in a second container containing the particle removal liquid; and

where the transducer activation mechanism activates at least the I' transducers in the particle removal liquid, and allows at least one cavity produced by at least one of the I' transducers to collapse and to thereby remove at least one particle on the surface immersed in the particle removal liquid.

14. A method for removal of one or more particles on a surface, the method comprising:

providing a first liquid container containing a selected particle removal liquid;

providing (i) a first transducer on a first container wall and (ii) a second transducer on a second container wall that is spaced apart from and faces said first container wall;

positioning an object in said container; and

activating the first and second transducers at respective first and second activation levels so that a concentration of said acoustic cavities generated in said removal liquid is approximately uniform along a line segment extending between said first container wall and the second container wall.

15. The method of claim 14, further comprising configuring said first transducer and said second transducer so that (1) said concentration of said acoustic cavities generated by said first transducer decreases approximately monotonically as a location on said line segment moves from said first container wall toward a center of said line segment and (2) said concentration of said acoustic cavities generated by said second transducer decreases approximately monotonically as a location on said line segment moves from said second container wall toward the center of said line segment.

16. The method of claim 15, further comprising:
providing (iii) a third transducer on said first container wall, adjacent to said first transducer and (iv) a fourth transducer on said second container wall, adjacent to said second transducer, where the third and fourth transducers are configured so that (3) concentration of said acoustic cavities generated by said third transducer increases approximately monotonically as a location on said line segment moves from said first container wall toward said center of said line segment and (4) concentration of said acoustic cavities generated by said fourth transducer increases approximately monotonically as a location on said line segment moves from said second container wall toward said center of said line segment.
17. The method of claim 15, further comprising causing an acoustic field generated by at least one of said first transducer and said second transducer to rotate with passage of time in a plane containing said line segment that extends between said first container wall and the second container wall so that said concentration of said acoustic cavities generated in said particle removal liquid varies with the passage of time.
18. The method of claim 15, further comprising generating said acoustic cavities generated by at least one of said first transducer and said second transducer so that said concentration of said cavities is non-uniform along at least one second line segment within said particle removal liquid that extends substantially parallel to at least one of said first container wall and said second container wall.
19. The method of claim 14, further comprising configuring said first transducer and said second transducer so that (1) said concentration of said acoustic cavities generated by said first transducer increases approximately monotonically as a location on said line segment moves from said first container wall toward a center of said line segment and (2) said concentration of said acoustic cavities generated by said second transducer increases approximately monotonically as a location on said line segment moves from said second container wall toward the center of said line segment.
20. The method of claim 14, further comprising configuring said first transducer and said second transducer so that said concentration of said acoustic cavities

generated in said particle removal liquid is approximately equal to a + b.cosh{α (x-L/2)}, where a, b and α are selected constants with b and α positive, x is a location coordinate measured in a direction extending between said first and second container walls, and L is a distance of separation between said first and second container walls.

21. The method of claim 14, further comprising configuring said first transducer and said second transducer so that said concentration of said acoustic cavities generated in said particle removal liquid is approximately proportional to a + c.exp{-β2(x-L/2)2}, where a, c and β are constants, with c and β positive, x is a location coordinate measured in a direction extending between said first and second container walls, and L is a distance of separation between said first and second container walls.

22. The method of claim 14, further comprising configuring said first transducer and said second transducer so that said concentration of said acoustic cavities generated in said particle removal liquid is approximately proportional to

$$a + b \times \cosh\{\alpha(x - L/2)\} + c \times e^{\{-\beta^2(x-L/2)^2\}}$$

where a, b, c, α and β are constants, with b, c, α and β positive, x is a location coordinate measured in a direction extending between said first and second container walls, and L is a distance of separation between said first and second container walls.

23. The method of claim 19, further comprising causing an acoustic field generated by at least one of said first transducer and said second transducer to rotate with passage of time in a plane containing said line segment that extends between said first container wall and the second container wall so that said concentration of said acoustic cavities generated in said particle removal liquid varies with the passage of time.

24. The method of claim 19, wherein said concentration of said acoustic cavities generated by at least one of said first transducer and said second transducer is non-uniform along at least one second line segment within said particle removal liquid that extends substantially parallel to at least one of said first container wall and said second container wall.

25. A system for removal of one or more particles on a surface, the system comprising:

a first liquid container containing a selected particle removal liquid;
a first transducer on a first container wall and a second transducer on a second container wall that is spaced apart from and faces said first container wall wherein the first and second transducers are activated at respective first and second activation levels so that a concentration of said acoustic cavities generated in said removal liquid is approximately uniform along a line segment extending between said first container wall and the second container wall.

26. A method for removal of one or more particles on a surface, the method comprising:
immersing at least a portion of a surface, having at least one particle that is to be removed from the surface, in a selected particle removal liquid in a liquid container;
positioning one or more activatable transducers in contact with at least one of the removal liquid and the container, where each transducer is capable of generating at least one cavity in the removal liquid and where the generated cavity subsequently collapses and provides a mechanism for removal of the at least one particle on a surface suspended in the particle removal liquid;
introducing a selected concentration of a selected cavity enhancement liquid into the removal liquid;
activating the one or more transducers to a selected energy level to initially generate a plurality of cavities within the combined removal liquid and cavity enhancement liquid;
when a selected density of cavities is established in the removal liquid, reducing at least one of (i) the concentration of the cavity enhancement liquid to a selected reduced concentration level and (ii) the activation energy of the one or more transducers to a selected reduced activation energy.
27. The method of claim 26, further comprising immersing the surface, or portion thereof, in the selected particle removal liquid after activating the transducers to the selected energy level.
28. The method of claim 26, wherein activating the transducers to the selected energy level occurs slowly.
29. The method of claim 26, wherein the inert fluid is introduced after cavitation energy is approaching an asymptote.

30. The method of claim 26 wherein said one or more transducers includes an assembly of two or more transducers.
31. A system for removal of one or more particles on a surface, the system comprising:
a liquid container containing a selected particle removal liquid and configured to receive at least a portion of a surface, having at least one particle that is to be removed from the surface;
one or more activatable transducers, positioned in contact with at least one of the removal liquid and the container, where each transducer is capable of generating at least one cavity in the removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of the at least one particle on a surface suspended in the particle removal liquid, and where the removal liquid initially includes a selected concentration of a selected cavity enhancement liquid;
a controllable transducer activation mechanism to activate the one or more transducers to a selected energy level to initially generate a plurality of cavities within the combined removal liquid and cavity enhancement liquid, wherein, when a selected density of cavities is established in the removal liquid, at least one of the following actions is taken: (i) the concentration of the cavity enhancement liquid is reduced to a selected reduced concentration level and (ii) the activation energy of the one or more transducers is reduced to a selected reduced activation energy.
32. A method for removal of one or more particles on a surface, the method comprising:
providing a liquid container with a selected particle removal liquid, where the container has at least one container wall that includes an array of at least one activatable transducer capable of generating acoustical cavities in the removal liquid;
positioning an array of at least two spaced apart acoustical cavity sensors within the removal liquid, spaced apart from the container wall that includes the at least one transducer;
activating the at least one transducer to generate an array of acoustical cavities in the removal liquid, and determining a time average of a distribution of cavities

D(x,y;avg) produced at I selected locations (I≥2), (x,y) = {(x_i,y_i)}i between the at least one transducer and the at least two cavity sensors;

comparing the time averaged distribution of cavities sensed at the selected locations with a reference distribution of cavities D(x,y;ref) at corresponding locations; and

when the time averaged distribution of cavities differs from the reference distribution of cavities by more than a threshold amount at the selected locations, interpreting this condition as indicating that the array of transducers is not performing acceptably.

33. The method of claim 32, further comprising:

when said time averaged distribution of cavities differs from said reference distribution of cavities by no more than said threshold amount at said selected locations, interpreting this condition as indicating that said array of transducers is performing acceptably.

34. The method of claim 32, wherein an extent by which said time averaged distribution of cavities D(x,y;avg) differs from said reference distribution of cavities D(x,y;ref) is determined by a process comprising:

forming a selected combination C{D(x,y;avg),D(x,y;ref)}, where the combination is homogeneous with a selected degree of homogeneity b (≥0) in said time averaged distribution and said reference distribution at said selected locations, and the selected combination C satisfies C{D(x,y;test),D(x,y;test)} = 0 for an arbitrary test distribution D(x,y;test) of said cavities, defined at said selected locations.

35. The method of 34, further comprising choosing said selected combination C of said time averaged distribution of cavities and said reference distribution of cavities to be

$$C\{D(x,y;avg),D(x,y;ref)\}=\left\{\sum_{i=1}^{I} w_i\left|D(x_i,y_i;avg)-D(x_i,y_i;ref)\right|^m\right\}^{1/m}$$

where {w_i}i is a sequence of selected non-negative weight coefficients, whose sum equals 1, and m is a selected positive constant.

36. The method of claim 34, further comprising choosing said selected combination C of said time averaged distribution of cavities and said reference distribution of cavities to be

$$C\{D(x,y;avg),D(x,y;ref)\}=\left\{\sum_{i=1}^{I} w_i\left|D(x_i,y_i;avg)/D(x_i,y_i;ref)-1\right|^m\right\}^{1/m}$$

where $\{w_i\}i$ is a sequence of selected non-negative weight coefficients, whose sum equals 1, and m is a selected non-zero constant.

37. The method of claim 34, further comprising determining if said time averaged distribution differs from said reference distribution by more than said threshold amount by determining if C{D(x,y;avg),D(x,y;ref)} is greater than a selected threshold value C_{thr}.

38. The method of claim 34, further comprising choosing said selected combination C of said time averaged distribution of cavities and said reference distribution of cavities to be

$$C\{D(x,y;avg),D(x,y;ref)\}=\left\{\sum_{i=1}^{I} w_i\left|D(x_i,y_i;avg)/D(x_i,y_i;ref)\right|^m\right\}^{1/m}$$

where $\{w_i\}i$ is a sequence of selected non-negative weight coefficients, whose sum equals 1, and m is a selected non-zero constant.

39. The method of claim 34, further comprising determining if said time averaged distribution differs from said reference distribution by more than said threshold amount by determining if C{D(x,y;avg),D(x,y;ref)} is less than a selected threshold value C_{thr}.

40. A system for removal of one or more particles on a surface, the system comprising:

an array of at least two acoustical cavity sensors, spaced apart from a surface that includes at least one transducer in a particle removal liquid;

a transducer testing mechanism to activate the at least one transducer to generate an array of acoustical cavities in the removal liquid, and to determine a time average of a distribution of cavities D(x,y;avg) produced at I selected locations (I≥2), $(x,y) = \{(x_i,y_i)\}i$ (i = 1, ... , I) between the at least one transducer and the at least two cavity sensors; and

a comparison mechanism to compare the time averaged distribution of cavities sensed at the selected locations with a reference distribution of cavities D(x,y;ref) at corresponding locations so that, when the time averaged distribution of cavities differs from the reference distribution of cavities by more than a threshold amount at the selected locations, the comparison mechanism

interprets this condition as indicating that the array of transducers is not performing acceptably.

41. A method for removal of one or more particles on a surface, the method comprising:
providing a first liquid container containing a selected particle removal liquid;
providing a thin sheet of a selected material at an exposed surface of the removal liquid so that a first surface of the thin sheet is contacted by the removal liquid;
providing at least one transducer adjacent to a selected first wall of the container;
positioning a first surface of a first object in the first container, where the first surface has a first end and a second end, the first end of the first surface is adjacent to the at least one transducer, the second end of the first surface is adjacent to the thin sheet, and the first surface has at least one particle to be removed therefrom;
providing a test liquid in contact with a second surface of, and on an opposite side of, the thin sheet from the thin sheet first surface;
positioning a light sensor adjacent to an exposed surface of the test liquid to receive and sense light produced in the test liquid; and
activating the at least one transducer to thereby generate and allow collapse of at least one acoustic cavity within the removal liquid, to thereby receive at the thin sheet first surface a first energy pulse arising from the collapse of the at least one cavity, and to generate in the test liquid a second energy pulse in response to receipt of the first energy pulse at the thin sheet first surface.

42. The method of claim 41 further comprising positioning a first surface of a second object in the first container, spaced apart from and substantially parallel to the first object, where the second surface has a first end and a second end, the first end of the second surface is adjacent to the at least one transducer, the second end of the second surface is adjacent to the thin sheet, and the second surface has at least one particle to be removed therefrom.

43. The method of claim 41, further comprising forming a light image of the second energy pulse corresponding to the first energy pulse.

44. The method of claim 43, further comprising converting said light image to a signal and adjusting at least one parameter of said at least one transducer if said signal is outside of a permitted range.
45. The method of claim 41, wherein said test liquid is disposed in test cells.
46. The method of claim 45, wherein said test cells are light-proof.
47. The method of claim 41, wherein said test liquid includes a noble gas.
48. The method of claim 41, further comprising introducing said test liquid via a liquid ingress system.
49. A system for removal of one or more particles on a surface, the system comprising:

    a first liquid container containing a selected particle removal liquid;

    a thin sheet of a selected material, positioned at an exposed surface of the removal liquid so that a first surface of the thin sheet is contacted by the removal liquid;

    at least one transducer positioned adjacent to a selected first wall of the container;

    where the first container receives a first surface of a first object in the first container, the first surface has a first end and a second end, the first end of the first surface is adjacent to the at least one transducer, the second end of the first surface is adjacent to the thin sheet, and the first surface has at least one particle to be removed therefrom;

    a second liquid container containing a test liquid in contact with a second surface of, and on an opposite side of, the thin sheet from the thin sheet first surface;

    a light sensor positioned adjacent to an exposed surface of the test liquid to receive and sense light produced in the test liquid; and

    transducer activation means to activate the at least one transducer to thereby generate and allow collapse of at least one acoustic cavity within the removal liquid, to thereby receive at the thin sheet first surface a first energy pulse arising from the collapse of the at least one cavity, and to generate in the test liquid a second energy pulse in response to receipt of the first energy pulse at the thin sheet first surface.

50. A system for removal of one or more particles on a surface, the system comprising:
shaft upon which an object having an object plane is disposed, said object having one or more particles on an object surface, said shaft and said object being positioned such that at least a portion of said object is immersed in a selected liquid, said shaft being ditherable to and from a position normal to said object plane by a specified angle range; and
at least one transducer capable of generating at least one cavity in the selected particle removal liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle attached to the surface suspended in liquid.
51. The system of claim 50, wherein said specified angle range is 0.2-10 degrees.
52. The system of claim 50, wherein said object is a wafer.
53. The system of claim 52, further comprising a wafer chuck, upon which said wafer rests, said chuck attached to said shaft.
54. The apparatus of claim 50, further comprising a pivot mechanism.
55. The apparatus of claim 54, further comprising shaft rotating means.
56. The apparatus of claim 54, wherein said liquid is a cleaning liquid.
57. A method for removal of one or more particles on a surface, the method comprising:
providing a shaft upon which an object having an object plane is disposed, said object having one or more particles on an object surface;
immersing at least a portion of said object within a selected liquid;
dithering said shaft to and from a position normal to said object plane by a specified angle range; and
providing at least one transducer capable of generating at least one cavity in the selected liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on the surface suspended in the particle removal liquid.
58. A method for removal of one or more particles attached to a surface, the method comprising:
holding an object having an object thickness on an object holder; and
allowing said object to move laterally a

distance of at least 0.1 times the object thickness while said object is held by said object holder and while said object is being said subjected to liquid cavitation.

59. The method of claim 58, wherein said object is allowed to move laterally a distance ranging from 0.1 -5 times the object thickness.
60. The method of claim 58 wherein said object is a wafer.
61. A system for removal of one or more particles attached to a surface, the system comprising:
object holding means holding an object having an object thickness and a surface having at least one particle on the surface, said object holding means being positioned to immerse at least a portion of said object within a selected liquid, said object holding means allowing said object to move laterally a distance of at least 0.1 times the object thickness while said object is held by said object holder and while said object is being subjected to liquid cavitation in said container; and
at least one transducer capable of generating at least one cavity in the selected liquid, where the generated cavity subsequently collapses and provides a mechanism for removal of at least one particle on the surface suspended in the liquid.
62. A method for removal of one or more particles on a surface, the method comprising:
determining a desired cleaning power χ with which to remove at least one particle on a surface suspended in a selected particle removal liquid;
calculating a number μ of adjacent transducers
required to achieve said desired cleaning power χ with the inverse of an expression $\chi = g\{f(u)\}$;
suspending the surface in the selected particle removal liquid;
immersing the calculated number μ of adjacent transducers in the particle removal liquid; and
activating the calculated number μ of adjacent transducers in the particle removal liquid to thereby generate and allow collapse of at least one acoustic cavity within the selected particle removal liquid to remove at least one particle on the surface at said desired cleaning power.

63. The system of claim 62, wherein the calculated number μ of adjacent transistors is 3, 5, 7, or 9.